pipe coils are-not stiffened with sand, they will either sag or sections will bend and move too close the hot face of the block. Either occurrence can render the cooling block unusable. The sand mix is removed after the casting has solidified.

In general, embodiments of the present invention strike a balance between the differential melting points, and the differential coefficients of expansion of the pipe and casting materials. High differential melting points are needed so the pipe does not melt or soften during casting, and so thin-wall pipes can be used that can be formed easily. But low differential coefficients of expansion of the pipe and casting materials are needed so that the yield strengths of the materials are not exceeded during operational thermal cycling. Copper alloys are, in general, preferred for the pipe and casting materials because of their superior thermal conductivity compared to material cost.

Therefore, the respective copper-alloys used in the pipe and casting must be sufficiently different to result in a maximal differential melting point, and sufficiently the same to result in a minimal differential coefficient of expansion. Given these general constraints, an empirical solution has been to make embodiments of the present invention with UNS-type C71500 copper-nickel alloy, and the casting with UNS C81100 cast copper. The thermal conductivity of the copper predominates, and the yield strength at the fused interface are not over-stressed by operational thermal cycling. Other UNS-type alloy combinations could no doubt be satisfactory, but these will all necessarily meet the general constraints mentioned herein.

The yield strengths of the pipe and casting both degrade as the copper content of the respective alloys increases. For example, the maximum copper casting stress at the pipe interface is almost linearly proportional from 8000 PSI at 30%-W copper to 2000 PSI at 100%-W copper. The maximum pipe stress is almost linearly proportional from 14000 PSI at 30%-W copper to 2000 PSI at 100%-W copper.

TABLE II

Cu % - W	A	B	C	D	E	F
100	135	114	325	2228	2228	2 Grooves
70	158	115	349	5662	8195	2 Grooves
30	161	115	352	8303	14203	2 Grooves
70	158	115	229	5642	8166	Pockets

For an applied heat flux of 50,000 BTU/Ft^2/hr:
A =pipe temperature ° F., external;
B =pipe temperature ° F., internal;
C =copper temperature ° F., tip;
D =copper stress (PSI), at pipe;
E =pipe stress (PSI);
F =surface type.

FIGS. 4A–4D illustrate a cooling block embodiment of the present invention, and is referred to herein by the general reference numeral **400**. The cooling block **400** includes a hot-face **402** opposite to a plumbing face **404**. A pair of UNS C71500 copper-nickel alloy pipes **406** and **407** are fitted with respective pipe couplings **408–411**. The pipes **406** and **407** are cast inside a solid-copper block **412**. FIGS. 4A–4D show a typical pattern. A system of vertical grooves **414**, horizontal grooves **416**, and pockets **418** at the intersections are included in the hot face **402**. Such provide sites to retain refractory and/or frozen bath material. The use of any of the vertical grooves **414**, horizontal grooves **416**, and pockets **418**, as well as their shapes and placement are a matter of engineering choice made for each particular application. The fabrication of the cooling block **400** is similar to the furnace-cooling system **100** of FIG. 1.

Although particular embodiments of the present invention have been described and illustrated, such is not intended to limit the invention. Modifications and changes will no doubt become apparent to those skilled in the art, and it is intended that the invention only be limited by the scope of the appended claims.

What is claimed is:

1. A furnace-cooling system, comprising:

a pipe coil comprising a copper-nickel alloy comprising at least 60%-Wt copper, and for providing a cooling-water passage; and

a furnace-cooling block comprising a copper alloy comprising at least 50%-Wt copper;

wherein a circuit of the pipe coil is not cooled when being cast inside the furnace-cooling block.

2. A furnace-cooling system casting combination as it exists during its fabrication, comprising:

a pipe coil comprising a copper-nickel alloy comprising at least 60%-Wt copper, and for providing a cooling-water passage;

a furnace-cooling block comprising a copper alloy comprising at least 50%-Wt copper;

a packing of sand that fills the pipe coil during casting of the furnace-cooling block; and

wherein a circuit of the pipe coil is not cooled when being cast inside the furnace-cooling block.

3. A furnace-cooling system, comprising:

a pipe coil comprising a UNS C71500 copper-alloy and for providing a cooling-water passage; and

a furnace-cooling block made of a material that starts as a high purity copper equivalent to UNS C1100 cast inside a mold, and that ends with an approximation of UNS C81100;

wherein a circuit of the pipe coil is not cooled when being cast inside the furnace-cooling block.

4. The furnace-cooling system of claim **3**, wherein:

the pipe coil has a maximum wall thickness equivalent to ASTM Schedule-40.

5. The furnace-cooling system of claim **3**, wherein:

any stresses at an interface of the pipe coil with the furnace-cooling block of cast copper does not exceed a yield stress for the cast copper, based on three-dimensional finite element thermo-mechanical stress analyses, under design thermal loading.

6. The furnace-cooling system of claim **3**, wherein its constituent materials strike a balance between respective differential melting points and corresponding differential coefficients of expansion of a pipe and its surrounding cast materials, wherein a high differential melting point is required so said pipe does not melt or soften during a casting, and so a thin-wall pipe can be used that can be formed easily, and a low differential coefficient of expansion of said pipe and casting materials is required so that any yield strength of said constituent materials are not exceeded during a later operational thermal cycling.

7. A furnace-cooling system comprising:

a plurality of constituent materials that strike a balance between respective differential melting points and corresponding differential coefficients of expansion of a pipe and its surrounding cast materials, wherein a high differential melting point is required so said pipe does not melt or soften during a casting, and so a thin-wall

pipe can be used that can be formed easily, and a low differential coefficient of expansion of said pipe and casting materials is required so that any yield strength of said constituent materials are not exceeded during a later operational thermal cycling; and

copper alloys are used for said pipe and casting materials;

wherein, respective copper-alloys used in said pipe and casting are sufficiently different to result in a maximal

differential melting point, and sufficiently the same to result in a minimal differential coefficient of expansion.

8. The furnace-cooling system of claim 7, wherein:

said constituent materials comprise only UNS C71500 copper-nickel alloy and UNS C81100 cast copper.

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